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# Practical Hints

*for*

# Concrete Constructors

BY

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## PRACTICAL HINTS FOR CONCRETE CONSTRUCTORS.

I note in reading the engineering papers and other publications dealing with concrete construction that little is said about the general methods of design which govern first-class finished concrete work or the general methods necessary in the supervision of this class of work to attain satisfactory results. I hope that this article will be of sufficient interest to the readers of Engineering News to warrant them in discussing the subject of concrete along similar lines.

It is a lamentable fact that we do not succeed in getting as good results with finished concrete work as the French. The causes are various; they have been doing this class of work longer, use a better grade of mechanics and laborers, mix and place the concrete more carefully and study their designs more thoroughly, which results not only in getting a better class of concrete work, but in their paying a higher price for it, that is, on a comparative basis. Frequently concrete work in this country is forced for its existence to compete with timber and steel, and to do this means frequently unreasonably high stresses and, what is even worse, that the contractor does not get enough money to do first-class work.

In addition to this, we are handicapped by the fact that the concrete business has progressed

at such a rapid rate that it is difficult to get competent engineers to design and supervise the work intelligently, and even more difficult to get experienced foremen, inspectors and mechanics to look after the detail execution. Our materials are often unexcelled. Where concrete has been used for foundations, backing or to replace heavy masonry for culverts, bridges, buildings and other structures in localities where its appearance has not been vital it has met with almost absolute success. But where appearance, in exposed places, has demanded care and experience the results have been more often unsatisfactory.

The work is, however, greatly improving, and it is a pleasure to note that after years of labor the profession has been able to practically obliterate the serious hair-cracks which marred their early structures. Probably the most important general item in finished concrete work which is now engaging the labors of concrete workers is that of overcoming the efflorescence which disfigures so many of our concrete structures. This question, however, is as yet unsolved.

## Some Points in Detail Design.

The first thing that a concrete engineer has to do, after his general lines are laid out, is to select the general details of design. In this connection I have to call the attention of the inexperienced designer to the following, the greater part of which applies especially to bridge work:

The elastic theory as applied to concrete arches is very elegant and every concrete designer should be familiar with it, but in all cases except in that of very flat reinforced arches the common theory, intelligently applied, is all that is necessary. In the design of the Piney Branch bridge,

now under construction in Washington, both theories were applied and the maximum pressures differed under the two analyses by only 5 lbs. per sq. in.

Don't spend much time worrying about the exact position of the neutral axis of a beam. After you have inspected work under construction for a time you will be convinced that the way concrete goes into the work does not permit of any hair-splitting application of theory.

Don't stress your concrete in compression higher than 300 lbs. per sq. in. (mixture 1:2:5) in beams, columns or arch-work, unless you are going to have first-class inspection; 400 lbs. per sq. in. is high enough when the work is going to receive the best class of inspection. It is true that the French use very much higher stresses in their work, but they do a better class of work than we are at present doing in this country.

Select a design which gives little tension or shear where possible. Remember that concrete is strong in compression and weak otherwise. The parabola catenary and circle are the best curves for a concrete arch. Arches designed on these lines require little steel reinforcement. Elliptical arches and basket handles and other flat arches must be heavily reinforced with steel and should not be used unless the waterway or grade demand it. Very flat arches act more like beams than arches, in spite of the elastic theory.

VARIETY OF MIXTURES.—In your plans and specifications for small work, don't call for two or three different mixtures of concrete where it is not necessary. You are figuring pretty close when you differentiate between, say, 1-2-4, 1-2½-5 and 1-3-6 mixtures. It is axiomatic that a 1-2-4 is stronger than a 1-3-6, other things being equal, but is the practical difference so

great that you cannot safely get along with a 1-3-6, or is the added cost of the material of the 1-2-4 really a matter of monetary import? If you study the ultimate crushing strength of the several classes of concrete, you will probably conclude that the practical difference as to compression is not great. I do not mean to say that you should not use a 1-2-4 for reinforced-concrete work or other high-stress design; but on plain, every-day work you will often find a 1-2-5 or 1-3-6 is amply strong for an entire job. In foundations you can frequently use a 1-3-7, 1-4-8 or 1-5-10 in perfect safety if you have good materials and good inspection. If you can in safety do so, specify one lean concrete for your foundations, say 1-4-8, and use a 1-2-5 (or depending on your aggregate a 1-2½-5) in your superstructure.

Frequently on small work with only one mixer the contractor would make money by placing the richer concrete throughout. I recall one design of my own where three mixtures were specified, where the leanest mixture was amply strong. This sort of thing doesn't cost your client any more, as a rule, because the contractor in making his bid doesn't have time to consider these hair-splitting points—but it costs him (the contractor) money that he hasn't figured upon.

STEEL REINFORCEMENT.—It is easier to design concrete work by using steel reinforcement than otherwise. The designer does not have to study his work as carefully in order to make sure that the concrete will not be subjected to tension or shear. When in doubt, reinforce with steel, as it is an axiomatic fact that in all cases it strengthens the work. Steel is particularly useful for beams, flat arches and structures whose foundations are poor (in order

to allow for deformation) and for reinforcing the foundations.

Concrete cannot be safely used as a beam without reinforcement except by using absurd depths. Frequently it will be found in figuring out the cost of designs that unreinforced concrete will be cheaper than reinforced concrete on the basis of the same factors of safety because of the additional expense required in reinforced work for forming steel and the additional cost of placing concrete in narrow forms. In one piece of work under my supervision which consists of very small ornamental reinforced houses, the actual cost was almost as much as it would have been for cut granite.

Bars having a mechanical bond are stronger than plain rods, particularly in work where the inspection is not the best. Bars having a mechanical bond are particularly desirable in vertical and approximately vertical reinforcement, because in these positions they are frequently struck by the laborers and mechanics handling material on the work and not infrequently by the concrete buckets. When bars are so struck they lose their adhesion to the abutting concrete, if it is partially set up. This loss of adhesion, in bars of an inch thickness, will extend down as far as 18 ins. from the top surface of the concrete. This is one of the many reasons why light reinforcement (small bars in a larger number) is better than heavy reinforcement. When the adhesion is broken, you are forced to rely on the mechanical bond. Rods should not be placed closer to corners or other face work than three diameters. It is not uncommon, where the reinforcement is closer, that the concrete on the outside of the rods (particularly where the reinforcement is vertical) will spall off. Small mesh

reinforcement must not be used where the aggregate is large, as it is difficult to force the concrete through the mesh so as to completely encase it. It is well in design to keep in mind in a general way the practicability of holding reinforcement in place during the concreting. Reinforce all thin walls, particularly at their junction with other work—and amply, as they are easily thrown into tension. Do not put in an absurdly small quantity of steel in a large structure, as it has no motive.

In all designing in concrete, care should be taken not to suddenly change the cross-section from a heavy one to a thin one unless this is imperative. All quick changes from heavy to light section should be reinforced with steel. The greater the change, the greater amount of reinforcement is needed. Concrete in setting up acts a good deal like cast-iron does in solidifying and cooling, and the concrete designer should bear in mind this bad trait. In an article* by the writer on the Connecticut Ave. bridge, Washington, D. C., this trouble was exemplified in a small detail, which had to be changed for the reason noted; in this particular case, had we adhered to the original cross-section of the detail, I do not believe that any amount of reinforcement would have overcome the difficulty.

Abutments of U-shape built of unreinforced concrete frequently crack at or near the intersection of the wing-walls with the head wall. These cracks are caused by the outward rotation (in directions at right angles to each other) of the head wall and the side walls. The pressure at the toe of these walls being greater than at the heel, their outward rotation is evident, as-

*Engineering News, June 1, 1905, pp. 571-575.

suming the foundation bed to be compressible. The stresses engendered by this outward rotation are amplified by the bending of the walls considering them as cantilevers, fastened at the foundation. I noted recently in a wall 60 ft. high, designed on the basis of a base four-tenths the height, that the flexure amounted to about ¼-in. (Whether this was all due to flexure is problematical, not certain, although knowing the nature of the foundation bed I believe the movement was one of flexure.) The shearing and tensile strains caused by this combination of rotation and flexure, added to often by the unequal settlement of the foundations, cannot be resisted by unreinforced walls of ordinary thickness. Therefore I suggest heavy steel reinforcement at this junction of the walls, even where the walls themselves are not built of reinforced concrete.

If you can't afford to do this I would use tie-rods joining the side walls or I would build the head wall detached from the side walls. The lip which will form between the head wall and both of the side walls may be dressed off or be hidden in the design.

FOUNDATION CONCRETE.—On foundation work where mass is desired and reinforced concrete is not practicable, and where the supporting foundation bed will not safely stand more than two or three tons per square foot, a cheaper and frequently equally good foundation may be obtained by using a cheaper aggregate than first-class concrete stone. Broken brick, broken concrete, the softer varieties of rock, slag and cinder may be safely used for this class of concrete. In deep massive concrete foundations the weight of the foundation is often one-half the total weight which comes on the supporting bed.

In this connection attention should be called to the use of concrete piles for foundations which have to be carried to any great depth, particularly where water is to be encountered. In many cases I think the concrete pile will be found the cheaper foundation.

It is not uncommon to see a 1-2-5 mixture which would safely carry a load of 20 tons used in a large foundation where the supporting clay will only carry a couple of tons per sq. ft. Of course, in using lean mixtures it requires better mixing and better supervision.

Where first-class foundation soil cannot be economically reached, use reinforcement in the foundations to spread your load over the area and use a reinforced superstructure in order to lighten the loads on your foundation.

AESTHETIC APPEARANCE.—The monotonous uniformity of color in concrete work can be varied by using sands or crushed stones of different color and by using different kinds of tools in dressing the work. This method of varying the color is preferable to using artificial coloring matter, which, as a rule, bleaches out and weakens the cement.

If a structure is not to be tooled or finished by other means, its design should be simple in its architectural details, the beauty of the structure in this case being made to depend on the harmony of proportion. Such a structure should have filleted corners and well rounded details, simple moldings and large details in general, so that it will stand out boldly a confessed simple concrete structure. The excellent Thebes bridge approaches* and the Big Muddy bridge†, are good

*Engineering News, May 11, 1905, pp. 479-483.
†Engineering News, Nov. 12, 1903, pp. 423-429.

types of this class of concrete structure. Both of these bridges are in thinly settled districts, and fine details, particularly for a railway bridge, would be marks of poor design.

It is extremely difficult to build long reaches of plain walls quite plumb, and, therefore, even assuming that you are going to have first-class inspection on your work, it is well in the design to hide this class of defects by breaking up the plain surface by pilasters having projections from three inches to several feet. Belt courses should be used as often as consistent with appearances for a similar reason.

Don't use a very ornamental balustrade of concrete. If it is forced upon you I would suggest turning it over to one of the imitation stone companies who execute this special class of work. Remember that the balustrade or parapet receives constant close inspection by the public, who are accustomed to fine marble and granite details and are looking for it in concrete work, which is often made to simulate these materials.

Don't under any circumstances select marble details for concrete work. They are too fine. Select concrete details and you will get a better looking piece of work. If you want the best work which can be executed with concrete, trim your structure with stone block, or, if this is too expensive, with concrete blocks, cast separately, and afterwards dressed and set in place. In this way you are sure of your trimming (particularly your corners). Concrete is an excellent filler, not unlike rubble and brick, and in the best designs I think it should be used as a filler. There is no trouble getting good vertical plain faces by spading or building up the mortar face with the work, but corners and fine details give a lot of trouble.

Don't try to imitate stone work. Confess that

your structure is of concrete and design accordingly. Remember that concrete is a new material with new virtues and vices. Forms are permissible with this material that were impossible for the Greeks and Romans, and the older forms may not be possible in concrete. If the engineering conditions warrant a lintel 75 ft. long, don't make it look like an arch. It is not necessary. Don't dwarf your structure with excessive paneling, which suggests parlor furniture.

Don't cut up the arch rings into voussoirs by nailing strips on the lagging to make it appear that the arch is built of ashlar unless you are going to lay up the work in alternate transverse blocks, in which case it may be desirable. Don't make concrete imitate something that it is not.

Don't put a lot of gingerbread on a simple structure just because you can get it almost as cheap. Efflorescence does not mar simple details nearly as much as it does ornate ones.

Occasionally one sees a concrete bridge in which fine marble details are attempted [in many such cases the concrete is not tooled, and if you examine the structure you will find the balusters rough, their edges and corners broken, other edges ragged and thick, the base and top rail warped with unsightly edges, and the mortar joints varying between 1/16-in. and ½-in. to take up errors in casting], and in harmony with a marble design the lamps and other metal ornaments will be of bronze. This in my judgment is unfortunate. These finely wrought metal details can only succeed in showing how futile it was to attempt the fine details in concrete. Cast-iron is the best metal to use for such work. It bears about the same relation to concrete that bronze does to marble. Of course railings of wrought iron and steel would be permissible.

In this connection I wish to call your attention to the heavy balustrades and parapets of concrete used on light concrete bridges. This is particularly noticeable on flat reinforced-concrete arch bridges, whose beauty depends solely upon their correct proportions. A plain metal railing would frequently give a better balance and scale, and relieve the structure of the appearance that its sole duty was to support the parapet. Not infrequently you will see the coping, at the level of the bridge roadway, brought almost tangent to the extrados of the arch ring, giving an effect somewhat as suggested in sketch I of Fig. 1—and then this weak structure is loaded down with a heavy parapet. Of course, clearance occasionally demands that the coping be so placed; but when it does not, put it from 1 to 5 ft. above the crown of the arch or use a lighter railing.

On the other hand, a massive bridge needs a heavy parapet.

The use of keystones is deprecated, especially for reinforced-concrete arches built monolithically. They are without meaning.

I wish also to call your attention to the fact that heavier details—stronger projections—are required in concrete than in similar stone work. This, you will readily appreciate, is due to the fact that the arrises are not as fine as in the latter material. This is of particular import in a structure of great height.

Even more important, because necessitated by the requirements of good workmanship, is the shape given to projections and recesses. Sketch II of Fig. 1 brings out graphically the difference between stonework and concrete-work in this matter; the left-hand view shows a stone sec-

tion, the right-hand one a concrete section, both of the same general outline. The conditions surrounding the practical execution of concrete work require the heavy rounding of corners and strongly battered wash and draft slopes shown. The same principle applies to depressions, grooves, etc., as for instance the false joint-notches in rusticated work. Various ways of shaping these details are open to the designer; three of them are illustrated in sketches III, IV and V of Fig. 1. In the former, heavy rounding is used, to produce safe corners; in the second, the notch is triangular, with an angle of about 90°, giving perfectly free draft; in the third, the original square notch is modified by giving the sides such a batter that the lagging will draw away freely without risk of damaging the corners.

Besides having sufficient draft for free removal of forms, all rëentrant angles must be shaped with due regard to the flow of concrete around the projections of the forms. In sketch VI of Fig. 1 is shown an arch skewback with the end portion of the arch. If the arch concrete and the skewback concrete are to be placed at the same time, the concrete can reach face BB only by flowing around the projecting corner of the form, and if this corner is too acute an angle an imperfect surface at BB may result. It is important therefore to give face BB such a slope that the concrete can be forced against the form by the pressure of the concrete above. As shown in sketch the slope of BB is a little too flat, and should be made steeper. The same considerations affect the design of the coping shown in sketch VII, Fig. 1. If the slope of the coping is made as shown by the full lines, the forms can be built only as far as line a-a, in order to permit of tamping the concrete under the top of the

coping form; and the concreting must then be stopped until the forms for the parapet are erected. By sloping the upper surface of the coping as shown by the dotted lines, the concrete will be able to give a good face against a top form, so that the parapet can be concreted at the same time as the spandrel wall and coping.

FACE WORK.—Remember in block work used for trimming mass concrete (that is, work cast on the ground and set in place) that it is not, as a rule, cheaper to use thin veneers with 6-in. and 8-in beds. Use a bed at least equal to the rise. It does not cost any more money, and when you back it up with concrete it will stand the pressure of the wet concrete, and if you have sufficient bed, the blocks will be useful in fastening the forms of the mass work. Use hollow spaces or gouge spaces in the back of trimming blocks, to bond the blocks with the mass concrete.

Remember in block work when you cast brackets, dentils, coping etc. with over-hangs that you can bed these blocks better if they are made of such length that the center of gravity is a good distance from the edge of the masonry below. This costs very little more and will enable you to bed these overhanging stones without weighting down the back and will prevent excessive strain on the facing below the bed, which, as a rule, will not stand a concentrated pressure.

Long, thin concrete blocks to be cast on the ground and set in place should be reinforced with steel so that they may be safely handled.

Wherever the funds permit, concrete surfaces should be tooled, for appearance, excepting in very large structures where the imperfections on untooled concrete would not be noticeable.

When forms are removed the concrete surface

is as a rule unsightly. Parts of the structure executed upon different days, under different foremen, with sand and rock varying in color, show a decided difference in color. Also such parts of the structure as are laid up by dissimilar methods show a similar variation—for example, work which is cast against a form will have a different color from work composed of exactly the same kind of materials which has been trowelled in place; you will often notice this difference in color of coping and vertical wall. If forms are not oiled or soaped the knots will discolor the concrete, the print of each knot being clearly marked on the surface of the concrete in a brownish color. If they are oiled with a fatty oil, the oil will be in part absorbed by the concrete, making additional stains. Marks of the lagging are unsightly and the imprints of the grain give a woody appearance to the structure. The lipping of the different days' work makes the work appear ragged and this is added to by the roughness of the edges. You will also find the face is slovenly as a rule, and pitted with small water holes. Last but not least we have efflorescence.

Large masses of concrete having cross sections of over say 200 sq. ft. will frequently hair crack when the concrete sets up. In using the word hair crack in this connection I mean long, thin hair lines running vertically up the face of the mass work, sometimes at intervals of 10 and 20 ft. These hair lines are apparently independent of temperature and are due to the concrete in the face of the mass work setting up before the interior. These hair lines are not seriously detrimental to the structure nor are they noticed by laymen. However, on a "show job" you may overcome this trouble by using a light reinforcing of ex-

panded metal, wire mesh or light rods about 4 ins. from the face.

These defects are frequently obliterated in part by giving the structure a grout wash or a thin veneer of mortar. This method has been previously referred to, and in my judgment would better be omitted. The grout wash as a rule gives the appearance of paint carelessly applied and the thin veneer, unless applied by an expert hair-cracks and frequently, after a few years, peels off.

It is also common practice to wash the surfaces, using water and an ordinary scrubbing brush. This removes most of the bad effects, and, when in addition the edges are filed, presents a neat appearance, provided, however, the structure is built or at least faced with fine-stone concrete. The objection to this, however, is that the lagging must be removed in from 12 to 24 hours, depending upon the nature of the cement and other conditions governing time of setting—requiring especial care in the construction of the forming and adding considerably to the cost. On a small structure, a park bridge, for instance, the added cost should not be considered, as the effect is good; but in large structures, where the contractor's profit depends upon his ability to keep his concrete plant working, this added work in building the forms and the added work of their speedy demolition would, I believe, entail considerable cost.

Several years ago the District of Columbia built a small concrete bridge over Broad Branch,* of gravel concrete, the surface of which was washed as described and which gave a good effect.

*Illustrated and described in Engineering News of Jan. 22, 1903, p. 70.

The best way, however, of obliterating the unsightly appearance of unfinished concrete is to tool it, using a bush-hammer, crandall, point or pick, and using a chisel or file for the arrises. The spandrel walls of the Piney Branch bridge* now under construction are being tooled, using a small pick for this purpose. The effect is rustic and I believe pleasing. The concrete trimmings of the Connecticut Ave. bridge are being bush-hammered and the balance of the structure is being crandalled.

On large work permitting the use of air tools the concrete surfaces may be bush hammered or crandalled at an actual cost of from 1 ct. to 3 cts per sq. ft. Tooling a structure gives it a better appearance, removes form marks, lipping and efflorescence. Efflorescence may be permanently removed in this way, provided before its execution the drainage of water which has been carrying the efflorescence to the face of the wall has been cut off.

In dressing concrete surfaces, especial care should be taken to use sharp tools, otherwise the arrises will be bad, the surfaces will be marked with unsightly holes (caused by loosening stones, by dull tools) and the surfaces will be lifeless.

BLOCK FACING.—It is not necessary to plaster the backs of facing blocks or stones with cement mortar. This went out of fashion when wet concrete came in. Neither is it necessary to wet the backs of these blocks or stones, if you are backing up with wet concrete.

WATERPROOFING AND EXPANSION. — On large work make your stepping at the back of retaining walls in rises of about 4 ft.—smaller

*Engineering News, Nov. 16, 1905, pp. 510-512, and April 19, 1906, p. 453.

heights are unnecessary in large work and entail additional cost. Don't build the backs of concrete retaining walls on a batter as they are not as stable as stepped walls containing the same amount of masonry. Slope the treads of all steps at the back of retaining walls at least one inch to the foot if you want a dry showing face. This precaution is worth any amount of waterproofing. If you get pockets at the back of retaining walls which will hold water you can't expect the waterproofing man to prevent seepage.

Don't apply paper to vertical walls, as it frequently bulges, making pockets which hold water so that practically the water is forced through the wall. All that the back of a retaining wall properly built needs is a couple of coats of coal tar which must be applied when the surface of the concrete adjacent to it is dry, not superficially dry, but when the concrete is thoroughly set and the wall is dry for several inches in from the surface. Then place a light stone drain at the back of the wall as the backfilling is made. Then back up your weep holes with half a yard or more of broken stone; a handful of stone soon gets stopped up by silt.

It is a common error in subway construction to take great care in waterproofing the roof with often satisfactory results, but to take no precaution to carry this water over the expansion joint at the abutments. This results in the water running off the roof and down the face of the abutments.

In applying waterproofing on approximately horizontal surfaces apply the waterproofing in consecutive layers, after the method of shingling (the shingling should be done in the direction of the flow) and iron smooth upon the completion of these applications.

In waterproofing a flat surface I have to call attention to the loose skin method, which is probably as good as any other in use. This method consists of placing shingled layers of waterproofing paper, cemented together by a waterproofing composition, upon the surface of the concrete, without having the lower layers of the paper covering adhere to the concrete. The theory of this is, if the concrete cracks—and it generally does—the waterproofing layers will not crack with the concrete.

The engineer should try to localize the cracks by proper expansion joints and provide for these expansion joints in the waterproofing scheme. As in retaining walls, the best safeguard against leakage is to get the water away by drainage slopes, French drains, etc., bearing in mind in waterproofing that water takes the line of least resistance.

Provide for expansion in retaining walls by using construction joints about every 50 ft. Provide for uncertain foundations in a similar manner. Provide expansion and construction joints over arches. Use expansion joints at the abutments over piers in such work and construction joints on the haunches.

Expansion joints in retaining walls should be carried down to the foundation bed. It is not uncommon for engineers to start their expansion joints a few feet below the surface of the ground and not to carry them down to the foundation bed. This will often prove disastrous to the effective working of the expansion joint.

If it is economical to use an arcade of spandrel arches resting on your main arches, run the axes of these spandrel arches longitudinally rather than tranversely. Of course, this cannot be done if a vista is desired through the spandrel, or,

if on account of freshet or other local causes open spandrels are required. Longitudinal spandrel arches are easier to construct and simplify the expansion.

If concrete piers are subjected to the impact of heavy floes of ice they should be protected by a nosing of stone or iron.

Use fillets on all corners, excepting where the corners are built of coign blocks which have been cast separately on the ground and tooled before setting. It is practically impossible to get and maintain a fine arris by moulding concrete in place and, therefore, I suggest fillets. Concrete arrises are difficult to cast and maintain and, therefore, on dressed work I would file the edges to a ⅝-in. radius.

Gravel is practically as good as broken stone for aggregate, but concrete made of gravel cannot be tooled. Small deformations in the mold can therefore not be corrected in spaded gravel work.

When concrete is to be used as a beam or column, thin wall or arch, specify the best materials obtainable in your community. Concrete for this class of work must be carefully mixed and placed to produce a homogeneous mixture.

On work requiring various grades of concrete it is more than necessary in the specifications to vary the portions of cement, sand and stone. The quality of the materials might profitably be different and the method of mixing and placing concrete should be more careful for such work as beams than is necessary in mass work.

Many engineers seem to think that concrete is concrete and the same care should be taken in the proportions, mixing and placing in one case as in another. As a matter of fact, you can be a great deal more liberal with a contractor on

heavy foundation work than in building a reinforced beam, and the contractor should be given the benefit of this fact.

In designing assume that you are going to have unskilled mechanics to do your work. It is almost impossible to get a good concrete worker unless you educate him, and this is up to the engineer, his foreman or inspector. This is not the case on other classes of construction, where the details of construction can frequently be left to experienced mechanics.

Remember in designing and also in construction work, that concrete in setting shrinks and that there will always be a very small crack existing between abutting sections of concrete work executed at different times. Concrete which sets up under a head shrinks less. Concrete rich in cement shrinks more. Concrete made with coarse sand shrinks less than that made with fine sand.

Detail your bidding sheets so that the bidders can tell exactly the amount and kind of reinforcement required. Ask for prices on additional concrete of its several classes and for additional reinforcement of its several classes. You will find as the work progresses that there will be many places where extra concrete and extra reinforcement are desirable.

## Specifications.

Don't finally pass upon your specifications until your drawings have been finished and approved. Be careful to specify material which can be procured and preferably what is commonly in the market. This will save your client money and yourself considerable bother.

Don't specify methods of procedure on work in which you are not experienced. You can get experienced bidders competent to lay out their own

method of procedure; and if not, a closer study of the subject than is frequently possible in the writing of specifications will enable you later to determine upon better methods than can be decided upon off-hand.

Remember that no specifications at all is better than bad ones. Just say that the work shall be first class according to the common practice in your own vicinity (or some other, if it is better), which is about all that is intended by most specifications. If you take upon yourself the authority to specify in detail just exactly how a contractor is to proceed with the work, do not then specify that the contractor shall be responsible for the work. If you want the contractor to be responsible for the work, write a general specification describing the class and character of work desired, leaving the details to the successful bidder to work out.

Don't put things in the specifications which you do not mean to enforce, as it costs your client money and frequently keeps away desirable bidders. Sometimes engineers put in club clauses for the purpose of keeping the contractors in line. This is, of course, unnecessary.

Don't copy old specifications blindly. You can seldom use a standard specification for concrete without adapting it to local conditions. Don't preserve dead letters in your specification. Here are a few clauses which I incorporated in my own specifications in 1898, but which have been omitted in my more recent ones; I think they will still be found in use by a great many engineers in their specifications, but not in the actual construction:

Concrete shall not be passed down to its place through a chute or thrown or dumped from a height, but must be carefully lowered in a vessel and so carefully placed

as to contain the constituents evenly incorporated as mixed and entirely free from foreign matter of any kind.

Each batch of concrete shall be spread in place in horizontal layers not exceeding 6 ins. in thickness and shall be at once thoroughly compacted by ramming with rammers weighing about 25 lbs. each. Sufficient water must be used in making the concrete to enable the proper results to be obtained, but not enough to cause the concrete to quake under the rammer.

In regard to the second paragraph quoted, I wish to state that on a great deal of work where a reasonably rich concrete is in use it is neither impracticable in my judgment nor undesirable to bring the concrete up in 2-ft. layers if wet concrete is used. This, of course, is impossible when you get above ground, that is on finished work, as such a course would be too deep for the spaded face work. There is a tendency, I believe, in the profession to increase the layers on mass work, and I think possibly it results in getting better concrete. These large layers, of course, were impossible under the old system of using dry concrete. As to the rammer referred to I might say that most work at present is spaded, the rammers only being used occasionally when a dry batch is brought on the work, more often by accident than design.

The use of fine sand for concrete is deprecated where the concrete will be highly stressed.

Good crushed rock makes the very best sand, but in passing upon crushed stone in lieu of sand look out for rotten dust. Rotten rock going through the crusher is, as a rule, crushed to dust.

Do not specify ornate details with spaded work nor fine arrises. If these are desired, use a mortar face or, what is better, use broken stone throughout from ¾-in. or ½-in. down, depending upon the size of details desired. Tests indicate that a concrete made of the small aggregate is practically as strong as concrete of a large aggregate for the same percentage of cement.

Plastering the surfaces of concrete before the next day's work is begun is unnecessary. Concrete should be kept wet as long as practicable, provided efflorescence is not more of a factor than 8 or 10% additional strength.

Concrete can be laid in cold weather in large masses in water and below the surface of the ground. One of the best ways to protect it below ground is to permit the water to rise up over night and then pump it out the following morning. The laitance and silt which accumulate under such procedure, of course, should be carefully cleaned off.

### Forms and Centers.

FORMS.—The engineer should carefully study the forming of the work to be done, prior to the award of contract, and should specify in a general way the class of work which will be required of the contractor.

A great deal of work is seriously marred by the lack of rigidity in the forms. Designers use the same size wales and studding, whether or not the work is to be carried up 2 ft. or 10 ft. The height of a day's work should be always considered in the design of form and the maximum height of a day's work used. Extreme care should be taken to reinforce corners of the framing. In designing forms for my own work I assume that concrete is a liquid of half its own weight; that is 75 lbs. per cu. ft. This rule has resulted very satisfactorily.

Forms should be designed so that they can be used in duplicate. It requires a great deal of study frequently to design the forms so that they can be so used, but it means a great deal of money in the contractor's pocket.

Bevel all small projections on forms for rustic

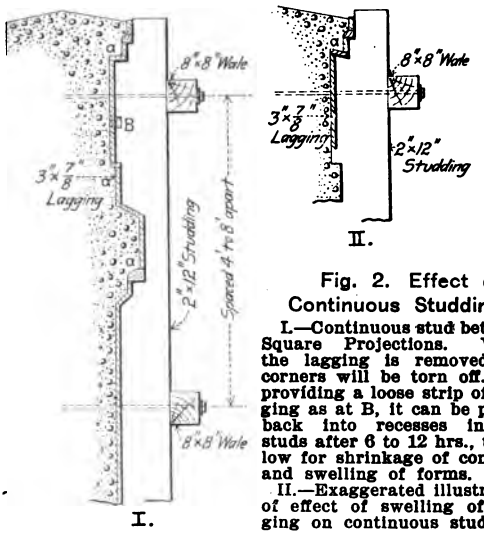


**Fig. 2. Effect of Continuous Studding.**

**I.—Continuous stud between Square Projections. When the lagging is removed the corners will be torn off. By providing a loose strip of lagging as at B, it can be pulled back into recesses in the studs after 6 to 12 hrs., to allow for shrinkage of concrete and swelling of forms.**

**II.—Exaggerated illustration of effect of swelling of lagging on continuous studding.**

joints, etc., so that these forms can be taken down without tearing off the edges of finished work. Bevel at least 1-16-in. to the foot. The designer of forms should always consider the practicability of the economical removal of forms without injury to the concrete.

Forms built up in section lengths should have these section lengths not longer than 6 or 8 ft. for convenience in handling and removal without injury to the complete work. For beams, camber the bottom of the forms slightly, so that any sag in the form will not give the appearance of sag to the beam.

In designing forming for finished concrete cast in place, the designer should be careful not to

use long, continuous studs cut out to the profile of the work as shown in sketch I of Fig. 2; if he does, it will be impossible to get the forming off without ruining edges a, a, a. The forms will be wedged tight at these points, as you will readily see. This wedging is due to the load of the concrete which is molded against the forms, and is made worse by the swelling of the lagging and studs caused by the water in the concrete. Sketch II, Fig. 2, shows an aggravated case of the swelling of the studs and lagging; you will note that the lagging is forced into the concrete so that corner "a" is sure of being broken when the forming is removed. To prevent this, in part at least, the following precaution is a good one: At every 3 ft. vertical, in a day's work, cut a piece of lagging into three parts as shown at B in sketch I. Then notch out the studs so that the middle portion of the lagging can be removed at any time by pulling back into the notch provided for it in the stud. When the concrete is six to twelve hours old, the middle slip should be pulled back as suggested. This is, I believe, an innovation of Mr. James Overn, C. E.

The use of short studs, with small wedges at dangerous corners, will prevent the troubles just referred to.

In designing forms, care should be taken to locate the forms in such a way that tie-rods will not come closer than 4 ins. to a projecting corner or other detail. If a rod is very close to a small detail there is a great chance of the concrete spalling off when the tie-rod is withdrawn from the concrete. The sketch Fig. 3 is an illustration of a bad case, where the tie-rod was located too close to the edge of a rustic joint.

The contractor should be required to stop up all cracks in the forms with mortar or putty, so

that the mortar will not give way. Tongue-and-grooved dressed flooring or similar lagging should be used on all face work, even if this work is to be dressed afterwards, because if these forms are not practically water-tight the mortar facing will get away, necessitating unsightly patches on the completed work.

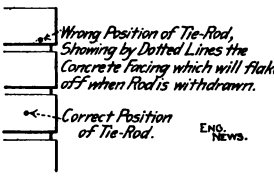
Wrong Position of Tie-Rod, Showing by Dotted Lines the Concrete Facing which will flake off when Rod is withdrawn.
Correct Position of Tie-Rod.
ENG. NEWS.

Fig. 3. Sketch Illustrating Proper and Improper Location of Tie-Rods with Respect to Face Details.

There is no practical difference in the appearance or strength of concrete, whether wood, sand, galvanized iron, cast iron or plaster paris is used in the face work forms.

ARCH CENTERS.—It is thought that better results can be obtained, and also a lower price secured, for the work, if the engineer designs the centering before bids are asked. It is certain that it gives the average contractor an opportunity to make a more intelligent bid. If the engineer is not experienced in this class of work, I would suggest that he leave the design entirely in the hands of the contractor, not attempting to cover the description of the center except in a very general way. I would suggest the following specifications for an inexperienced engineer:

Complete drawings of the centers with a complete description of the various materials to be used shall be submitted by the contractor to the engineer.

The center shall be built for the full width of the bridge, and the crowns of the centers shall be raised above the intended height of the finished arches to allow for settling when the centers are being loaded and when

struck. The centers shall be provided with striking wedges or sand boxes so that the lowering of the center may be effected slowly. The lagging for the center may be in two or more thicknesses if the contractor so desires, but the top layer shall be tongued and grooved lumber and the lower layers shall be dressed to match the top surface when in place. Lagging shall have a deflection under the full load of the arch of not more than ⅛-in. The settlement of the center under its full load shall not be greater than ¾-in. for each 30 ft. in vertical height.

Under such specifications the centering should not be paid for directly, but payment for same should be included in the price of the arch concrete in place. On large work I would suggest that the contractor be required to furnish ample fire protection. On one piece of work under my supervision, requiring nearly 2,000,000 ft. of lumber, the contractor installed a 4-in. water pipe, with hose connection for each arch.

The following was used in the specifications of the Piney Branch bridge. The center, however, with the consent of the contractor, was designed by the engineer:

20. FORMS.—All forms for all classes of concrete shall be closely laid and strongly braced. The contractor shall, before proceeding with the work, submit drawings of the forms to the engineer for his approval. All lagging shall be tongued and grooved, and the studding for all the work shall be dressed or sawed to an even thickness. All forms except by the consent of the engineer shall be held in place by means of bolts, so made that the outer 3 ins. of the bolts can be removed after the forms are taken down, and the remaining holes shall be filled with mortar (1-3). If ⅞-in. lagging is used the studs shall not exceed 18 ins. on centers, and if 2 × 8-in. studs are used the wales shall not be less than 8 × 8 in. These wales on a basis of 2 × 8-in. studs shall not be further apart than 8 ft., nor shall the bolts which hold them and which will have diameters of ¾ in. be further apart than 8 ft.

If lagging studs, wales or bolts are proposed by the contractor other than those described hereinbefore, they shall be such as to make a form of equal strength and stiffness to that described.

Washers shall be used under all bolt heads and nuts, and before proceeding with the concrete work forms shall be brought true to line and grade and all bolts shall be taut.

27. CENTERS FOR ARCH.—Complete drawings of the centers with a description of the various materials to be used shall be submitted by the contractor to the engineer, free of cost to the District of Columbia, and no work shall be done on the construction of the said centers until said drawings have been approved in writing by the engineer.

28. GENERAL DESCRIPTION OF CENTERS.—The centers shall be built for the full width of the bridge (25 ft. between faces of arch rings). The contractor will not be allowed to use centers having trussed spaces greater than 20 ft., but must carry posts down from the bow to suitable foundation. Bows in no case shall exceed 6 ft. 6 ins. on centers. They shall be stiffly sway-braced, both transversely and longitudinally. The foundations for the centers shall be of concrete of the same kind and according to the specifications hereinbefore specified for the permanent work. They shall be of such size as will not permit of a settlement greater than ¼-in. under the maximum loads they are designed to carry. The tendency of the centers to rise at the crown as they are loaded at the haunches must be provided for in the design, or if not the centers must be temporarily loaded at the crown and the load so regulated as to prevent distortion of the arch as the work progresses.

29. MATERIALS.—Merchantable long-leaf pine lumber (in accordance with the specifications adopted by the Southern Lumber and Timber Association, Feb. 14, 1883), shall be used throughout, excepting that sills, corbels, wedges and all other lumber subjected to side pressure shall be of white oak of the following specifications: White oak must be free from decay, splits, shakes, sawed true and out of wind, and square-edged, full-sized, free from large or loose knots or any other defects which would seriously impair its strength or durability. The wedges shall be of straight-grain oak only. All material shall be subject to the approval of the engineer. Stresses in all material for the centers will be computed on the basis of one-fifth of the breaking strain of the material used, in accordance with the tables of Messrs. Kidwell and Moore for wooden beams and columns, 1899. In the design of the center care shall be taken so that the center will be stiff. The joists, caps and bows shall not have a deflection exceeding ¼-in. under the full load of the arch, or the partial load of the arch, the concrete being figured as a liquid having a weight of 150 lbs. per cu. ft.

30. JOINTS.—No dependence will be placed in nails, except for fastening the lagging, for securing the wedges and for minor details, and then only upon the approval of the engineer. All joints shall be made with bolts and with straps or gussets of steel or iron, if in the judgment of the engineer they are necessary in the design submitted.

31. LAGGING.—The lagging may be made in two thicknesses if the contractor so desires. The top layer to be tongued and grooved lumber not less than ⅞ in. thick and the lower layer dressed to a matched top surface when in place. Lagging shall not have a deflection under the full load of the arch or under the partial load exceeding ⅛ in. The concrete being figured for partial load as a liquid having a weight of 150 lbs. per cu. ft. The lagging shall be kept wet for three weeks after the keying of the arches.

32. STRIKING CENTERS.—The crowns of the centers shall be raised above the intended height of the finished arches to allow for settling when the centers are being loaded and when struck. The centers shall be struck when directed by the engineer, which direction will not be given until the masonry above them has been completed up to the level of the bottom of the coping. Wedges shall have a batter of (one inch in ten), and the pressure per square inch on the same shall not exceed 300 lbs. per sq. in. The grain of same shall run with the batter and their contact faces shall be planed true and smooth for their entire width and length, and if so ordered by the engineer, they shall be lubricated to facilitate the striking of the centers without unnecessary jar. If the contractor wishes to use sand boxes to lower the centers, he shall submit details of the same for the approval of the engineer. The said boxes shall be waterproof and the sand used in the same shall be thoroughly washed to remove all silt and thoroughly dried before using. The centering shall not be paid for directly, but the payment of the same shall be included in the price for the arch concrete in accordance with the schedule of prices hereinafter to be determined upon.

## Engineering Supervision.

On small work it is necessary frequently to get along with a single inspector, whose duty it is to see that the forms are erected on the lines given by the engineer; that these forms are stiff; that the materials and workmanship are in accordance with the specifications and approved plans, and that the reinforcement is properly placed. In addition to this, he looks after the removal of the forms, to see that the concrete work is not injured in careless removal, and that all corners are properly protected by wooden strips upon the removal of the forms. To this is

added, as a rule, the clerical work of keeping track of the extra work and also the general cost of the work in its several details.

If you have to break in a green man for this work, I would suggest selecting a carpenter. It is more difficult to get a good man to look after the forming than any other part of the work, excepting that of getting a good face, and if you have not a man experienced on face work you had better camp out on the job when it comes to this part of the work. Contractors will help themselves a good deal by getting experienced foremen and mechanics for face work. Wood butchers and cheap labor will not pay a contractor who is trying to get a high grade of finished work. Contractors should bear in mind that finished concrete work requires skilled labor, just such labor as is required for first-class stone and brick work.

On any work, say, over $20,000, to be executed in a working year, I would suggest placing an additional low-grade inspector on the mixer. It occasionally occurs that the laborer pouring in the cement, through carelessness, does not put in the right amounts, and I recall two cases on my own work when the cement was entirely omitted. Of course, on work executed in daylight this omission would probably be detected, owing to the variation in its general appearance and color, but on night work it might get into the work and afterwards cause serious trouble. It is also quite common for a laborer to throw out one-third or more of hard, lumpy cement without compensating for it. This does not make so much difference in mass work, but in thin work it is, of course, vital.

It has been my practice to prohibit finished

concrete work at night, although if the contractor would provide a sufficient number of arc lights there is no reason why the finished work cannot be so executed. Another reason for having an additional inspector on the mixer is that, as a rule, material is more or less superficially inspected by the engineer or inspector by going over the top of a car or barge and digging up a few pockets here and there. Both sand and gravel, however, frequently contain layers of mud near the bottom, which the additional inspector on the mixer would be able to see and condemn.

Lines and grades must be given more frequently on finished concrete work than on other classes of masonry, as it is difficult to correct small errors without unsightly results. It may be said in general also that the cost of inspection under existing conditions is higher, in order to get a first-class finished concrete job, than it would be for the same amount of brick or stone. It is thought that from 1½ to 2½% of the total cost of the work is a proper charge for inspection on first-class concrete work.

Records of the actual cost of all work should be kept where possible in order to determine upon the proper price for the extra work. The various inspectors and foremen under the direction of the assistant engineer should agree each day as to the actual cost of the extra work. Assistant engineers should go over the extra work at least twice a month with the contractor's superintendent, so that the detailed cost may be properly adjudicated while the several items are fresh in the minds of the entire force. Very complex bookkeeping details, of course, generally result in their untimely death before the completion of the work; or, what is worse, in the loss of efficiency in the engineering and inspection forces.

Clerical work is a serious problem to most first-class inspectors, and therefore their reports should be simplified for them as much as possible by the use of printed forms.

**Contractor's Plant and Construction Work.**

Don't hurry your contractor until he has had a reasonable time to get his plant together. Good work cannot be executed with a poor plant at what are ordinarily reasonable prices. It is suggested to the contractor to bear in mind that stone crushers and concrete mixers seldom have enough power behind them to produce their rated capacity. Concrete mixers should be selected which have been in successful use. To get concrete to and from the mixer is more difficult than to mix the concrete. Mixing by hand in small quantities and at isolated points is frequently cheaper than machine. A first-class concrete plant will cost from 5 to 10% of the total cost of the work. Besides handling concrete, the plant, as a rule, has to do the following work (difficult foundation not considered): Excavate, sheet pile, mix and transport mortar, mix and transport concrete, handle lumber for falsework and forms (including demolition), handle steel, coal, broken rock and back fill. Several of these items should be carried on at one time to execute the work economically, which gives preference, as a rule, to derricks rather than cableways.

MIXER.—In selecting a mixer, give preference to a batch mixer which has been in successful operation a number of years. In this connection, however, I wish to say that the best tests I have ever had were from a continuous mixer of the asphalt type, but I think it requires more careful inspection to use this machine than it does the batch mixer. In such work as arch work, where

a large monolithic day's work is necessary, be careful to select a mixer which does not easily get out of gear.

If the contractor is to use a machine which is not known to you, or if you are not satisfied with the concrete which it is turning out, I would suggest the following test. I have found it a very valuable one on my work. In one case I found that a mixer whose product did not size up well to the eye was only giving me 60% strength of what might be regarded as a first-class concrete. An experienced man would probably be able to detect the fact that the results were bad, but even experience can well be supplemented by practical test.

Take the concrete as it comes from the mixer, and from this concrete take several handfuls of mortar from different parts of the pile until you have a shovelful. Then, being careful not to mix this mortar at all, make six briquettes from it. Then take several shovelsful of concrete from different parts of the pile of concrete until you have enough for six cubes. These cubes should be at least four times as large as the largest dimension of the broken stone used in the concrete, and preferably they should be 12-in. cubes, if there is an accessible machine large enough to crush such a cube. In making up the cubes be careful not to mix the concrete. After you have made the briquettes and cubes just described, have the remaining concrete turned over by hand four times. Then repeat the sampling, making six briquettes and six cubes. Then store the two sets of briquettes and the two sets of cubes under exactly the same conditions and break them in from seven to thirty days. The latter is preferred if you can take the time. The tests of the second set of the briquettes and cubes should

not show an increase in strength of 10% over the first set. However, if over 10% and less than 15%, I would suggest a second test, the results of which should be final.

Lean mixtures require more mixing than rich ones. Dry mixtures require more mixing than wet ones.

In feeding a continuous mixer by shovel, see that all of the material is fed at the loading end. It is not uncommon to see at least one of the shovel men feeding his material at the dumping end. Permit the retempering of concrete where the set is not so hard as to require a pick, provided the practice is not habitual. Do not split hairs on the mathematical proportions of the several materials which make up your concrete. This frequently causes a lot of squabbling with the contractor without any good resulting from it. Don't make the contractor pick out every piece of string, twig or leaf which you happen to see going through the mixer.

## MATERIALS.

GRAVEL.—Do not accept slimy gravel (when wet), nor gravel containing many mud balls or a large percentage of gravel cemented with mud.

BROKEN STONE.—Do not accept stone with a large percentage of tailings, nor stone with more than 15% of stone dust, nor more than 1% of weathered rock, nor stone a noticeable percentage of which goes to pieces under the rammer. My objection to a large percentage of stone dust is that, as a rule, rock which, when crushed, gives a large percentage of dust generally contains considerable rotten rock, which is ground to dust in its passage through the crusher. In using run-of-crusher material, study crusher conditions so as to obtain a reasonably uniform product.

LARGE STONE INCLUSIONS.—The use of large stone in concrete is thought to be excellent in mass work, particularly for dams where weight and horizontal shear are factors. Further, their emplacement frequently results in less cost per cubic yard.

The methods of placing these large stones differ in nearly every community. In some cases the restrictions of the engineers are so great that the result is an additional cost rather than a saving. It is not necessary to plaster these stones, nor bed them in mortar, if they can be *dropped* into the work before the concrete is set. Neither is it necessary to select flat stones (in highly stressed concrete this may be a matter of argument) for this work.

The stones should be clean, far enough apart to be well encased in concrete, and the encasing concrete should be wet so as to be stamped into place by the laborers. Where the largest percentage of large stone possible is desired, I would suggest that the engineer state this fact, rather than a definite percentage. This percentage is of course a function of the kind of rock used by the contractor, and it is hard to stipulate on paper what the maximum possible amount wil be, before you have tried it.

CEMENT.—The cement house should be sufficiently large to store about 20% of the annual work, or, what is practically the same thing, it should be large enough for two months' storage. The house should be of such size that the cement can be piled and kept in separate carlots.

For mortar face work, samples should be taken from each barrel—for general work, on the basis of one sample to ten barrels; all bags sampled should be properly marked, so that they may be

resampled if necessary. Cement should not be stored in a damp place. Hard lumps should be thrown out and replaced by good cement.

Paper cement bags are not cheap as a rule. You can't chute cement furnished in paper, nor handle in any other practical manner, without injuring a large percentage of it. In addition to this, the great number of leaky bags are cause of contention between the foremen and inspectors.

SAND.—Sand should not contain more than 10% of silt, except where actual tests indicate that the sand proposed is as good as the average sand generally used in the locality where the work is being executed. In this connection I have to say that I recall a case of my own work where sand containing 16% of silt gave a very much better result than a sand containing no silt and which had been originally intended for filtration purposes. On waterproofing work, as a rule, a large percentage of silt is desirable up to, say, about 15%, but facing work should not, as a rule, contain over 5%, as the greater amount of silt in the concrete the greater amount of slime there will be carried to the face work.

In placing concrete upon a sand foundation containing a sand without any silt in it, I noticed that the concrete was being robbed of its water. We were putting in soupy concrete. Fifteen minutes after it was placed it was almost dry. Besides this, I noticed that where a layer was allowed to stand a few minutes without any abutting concrete the water of the concrete had washed a part of the sand out of the concrete and also a part of the cement. There was a ring of sand about 5 ins. from the end of the layer, and the cement was extended somewhat beyond that. The sand used was a fine sand in this case. As a result of this observation, I accepted a

coarse sand containing about 12% of silt, which held its water satisfactorily.

Sand Test.—On large work I have recently used the following method of testing sand, which has been quite satisfactory: Wash a considerable quantity of sand, separate the silt from it, then make up a special sample from the sand and silt that you have separated, so that this latter sample will contain the maximum silt allowed under the specifications. (If the contractor is furnishing sands from more than one locality, it will be necessary for you to make the test herein described from samples of each of the localities, as will readily be seen from the nature of the test.) Take the specially prepared sample just described and thoroughly mix the silt with the sand until the distribution is uniform. Then take a small portion of the proposed sample, about three thimblesful (on my own work I have given the inspector an ordinary test tube, with a mark on the test tube indicating the height of the final sample of sand required). Take this small sample of the prepared sand, drop it into a graduated beaker of clear water about 30 ins. high (on my own work I have used the local hydrant water, which is filtered and reasonably clear at all times of the year), shake well until the sample has been thoroughly washed. Then take a domestic pin, fastened horizontally on the end of a wire or small stick, and insert it in the top of the beaker. When it is lowered into the water the murkiness of the water tends to obscure the pin, and the deeper the pin the more it is obscured, until a point is reached when the pin passes out of sight (viewed from the top). Just when the pin reaches this point, its position with reference to the graduation on the beaker is to be determined by reading from the side.

Make half a dozen similar tests, using the prepared sand, and the average of these samples will be the correct gage for sand which does not contain over the stipulated amount of silt.

Of course, it is not necessary to sample every carload or barge of sand that comes in, as the bulk of it can be determined by superficial observation. If you are in doubt, however, take a number of shovelsful of sand from various parts of the car or barge, mix thoroughly and take out the necessary amount of sand for test. Drop same into the beaker, shake, lower the pin, and read the gage. If the pin is then lower than the gage, the sand has less silt than the maximum; if it is higher, it has more silt.

This is a very cumbersome thing to explain, but it is more practical than it sounds. When I first suggested it to the men engaged on the work, it was thought to be too hair-splitting to be of any practical value, but after it was actually put into use it was entirely satisfactory and enabled the men to make immediate tests of the sand instead of waiting half a day, which would be necessary under the common method; and it permitted a great many more samples to be taken. If you use it, it will take about an hour to get your first sample prepared and your gage determined, after which two or three minutes will enable you to make the test. (This system I first saw used by Mr. Allen Hazen.)

Condemn sand for a noticeable quantity of mud balls, regardless of test. In this connection an inspector should use some judgment as to the nature of the mud ball. Sometimes these mud balls are almost solid chunks of mud and at other times they contain nearly all fine quartz, with a very little mud.

Mesh determinations of sand and run of crusher concrete stone are useful to the engineer in passing on these materials.

An engineer should make briquettes of the different classes of sands on his work, in order that he will be certain whether or not he is warranted in accepting sand with a slight excess of silt rather than a finer or poorly graded sand which comes well within the specifications as to silt.

## CONSTRUCTION WORK.

FORMS.—See that the forms are built to the lines and according to the approved plans. See that the lumber is sound and all wale joints are well spliced; that lumber, where toe-nailed, is efficiently nailed; that all forms are plumb; that all form rods have washers under their heads and nuts; that they are taut when concreting is begun, and that they remain so during the progress of the work.

Forms are designed for a certain number of vertical feet rise for a day's concrete work. Find out how many vertical feet. If for any reason the concrete is changed from a dry concrete to a wet one, consider the number of feet rise permissible under the changed conditions. In this connection I wish to say that the keeping of forms plumb is the most difficult thing which devolves upon the engineer, the contractor and their assistants. The building of plumb vertical walls can only be obtained when everybody on the work looks out for them. I have seen some very excellent concrete work done in different parts of the country where nearly all of the concrete walls were as much as 2 or 3 ins. out of plumb.

Inspectors should report to the assistant engineer any undue cutting of washers into the wood; also all form rods which have broken un-

der the strain of the concrete. See that tongue-and-grooved dressed lumber is used where required.

Use sized studs for all finished work. See that the forms are held tightly when beginning a day's work. If they are not, the load of the fresh concrete will push out the forms, causing not only lipping, but the mortar above will flow into the crack thus formed between the lagging and the old concrete, which will make a hole in the face work. See that heavy reinforcement is placed within the forms before the form tie rods are placed, as these tie rods frequently interfere with the placing of heavy reinforcement. Forms for finished work must be held together by tie rods with coupling placed at least 3 ins. from the finished face to permit of removal of all iron within 3 ins. of the finished face. This is done in order to prevent rust stains. Forms may be held by wire on unfinished work.

Have the contractor so lay out his work that he will reduce the walking over and the working on on all setting concrete to a minimum. Allow the contractor ⅜-in. departure from established lines on finished work and 2 ins. on unfinished work. (The latter may be increased indefinitely, depending on the size and nature of the work, but as a general rule the forms should be within 2 ins.)

BLOCK WORK.—Soupy concrete—that is, concrete which contains about one more bucket of water than the concrete specified for mass work—should be used on block work. This will enable the molders to bring out the details and arrises more strongly.

Facing stone dust or grit and facing sand should all have all coarser material removed by screening; ½-in. mesh is small enough for large

blocks and large details; use ⅜-in. mesh for fine work. Be careful, in passing upon the stone dust, that it does not contain a large percentage of rotten rock. All mud balls must be removed for facing work. The backs of all blocks should have recess places in the back covering practically one-fifth of the area in the back for the purpose of bonding with the mass. These recesses may be best obtained by placing wooden blocks, say, 6 × 6-in. or 8 × 8-in., in the concrete when first deposited and removing same before final set.

Cast all blocks with most important face down. All other showing faces should be cast vertical, or as near vertical as practicable. The back of the block—that is, that portion of the block which will not show in the structure—should always be molded up, because the laitance or slime always rises to the surface, giving it not only a bad color, but a weak surface, and one which is certain to hair-crack. All blocks should be molded in forms which are level—that is, which rest on a level platform—and great care should be taken by the inspector to see that the forms are stiff and do not bulge or distort under the concrete. If this is not done, the contractor will find it necessary to do a great amount of cutting, which in many cases will result in going through the mortar facing in order to get the block out of wind. All blocks should be left on their bottoms from two days to two weeks, depending on the size of the block and the nature of the cement and the condition of the weather. If not, they will be liable to break in handling.

Concrete should not be dressed (tooled) until 30 days old, under normal conditions, preferably not under 60 days. Before casting the several classes of block it should be agreed between the

contractor and the inspector as to the method of handling the block, so that there will be no dog or lewis holes in the showing faces. I found on my own work that this question is overlooked frequently in the design and molding of the blocks.

Lewis holes should be cast in the blocks where practicable. Bear in mind that lewis holes must be so made as not to bring excessive pressure on the concrete, particularly near the mortar facing or near the arrises of the block. Remember that you are not handling granite. Be careful not to handle large blocks with lewises or dogs when they are green, as you will meet with disaster. The contractor must provide wood blocks and rag cushions in turning over the blocks; otherwise the arrises will be broken.

One-quarter to ⅜-in. should be allowed beyond all neat lines for dressing. All arrises should be chiseled. Better work can be gotten by using hand hammers than machine ones, and concrete details subject to close inspection by the public should be hammered by hand. All arrises excepting those of abutting joints should be rounded to approximately a ⅜-in. radius. If this is not done, the public will eventually knock off the fine arrises. Use metal templets for cutting important details.

Modify all blocks which you are unable to cast satisfactorily. Inspectors should report all blocks which in their judgment need additional reinforcement. Check all forms just before molding and keep a record of the blocks cast and see that they are being cast in the order required on the work. Paint the date of casting on each block and keep careful record of them.

Cover all blocks in warm weather with rags, bags, etc., keeping same covered and damp for

ten days. Do not cast blocks in freezing weather (particularly thin ones) without taking extraordinary precautions to protect the concrete from the cold.

CONCRETE MASS WORK.—The inspector in charge of the mass work shall, before the mass concrete work is begun, receive from the form inspector an approval of the forms or shall personally examine them to see that they conform to line and grade, and that they are in accordance with the approved plan. He shall note before beginning this work that all laitance, mud, chips and dirt has been cleaned off the surface of the concrete, and that the forms (for finished work) are also cleaned of all dirt and cement. A very unsightly face is often produced by leaving the mortar on the forms, which has resulted by the throwing of concrete into the forms in the previous day's work. He shall be governed by inspections from the assistant engineer as to the height which the contractor may be permitted to carry up a day's work.

Concrete shall be placed in 9-in. courses on finished work. With the consent of the assistant engineer, concrete may be placed in courses of 2 ft. on heavy mass unfinished work.

Placing wet concrete in deep layers or breasts, as 2 ft., may be done not only in foundation work but also in heavy work above ground where there is to be a facing of ashlar (as commonly practiced by railways) or where the appearance of the face is not a matter of import.

In dumping concrete in narrow forms for thin walls and columns the contractor will find it advantageous to use a bucket with a narrow outlet controlled by sliding gates (Hains), so as to be able to dump the concrete into the forms in comparatively small quantities. A great

many tie-rods are broken in dumping large quantities of a yard or more with the ordinary side or bottom-dump bucket, and many more tie-rods are bent, thereby distorting the forms. The type of bucket suggested is also a material advantage to the contractor because it diminishes the cost of spreading the concrete.

On finished work each day's work shall be brought accurately to horizontal and vertical surfaces. If this is not done the lipping which nearly always shows will be ragged, and therefore unsightly. The positions of bulkheads and the height to which the finished work shall be carried shall be so selected as to assure a neat bonding appearance in the finished work. The contractor should so arrange his work that the concrete may be brought up at least 2 ft. in a day's work.

In jacketing steel beams and girders, the jacketing of a day's work should not be stopped at the level of the top of the top flange, because if this is done the concrete, which shrinks when it sets up, will not be snug against the under side of the beam or girder. This small space between flange and concrete can never be filled up. A day's work should be kept several inches below the top flange, or be carried up several inches above, so that the concrete will set up against the flange under a head.

Don't finish the day's work too close to an ornamental detail. You will find, if you do, that you have lipping where you can least afford it.

In waterproofing flat concrete surfaces with consecutive layers of tar or other similar material, apply the layers so that they will be shingled with the direction of the flow of water and iron well. Don't apply waterproofing material rich

in water; that is, which is full of water bubbles. On extra work the contractor is entitled to pay for moving his plant or machinery to and from another part of the work, provided the extra job is on a part of the work previously declared finished by the engineer.

Breaking into the contractor's gangs for men on odd extra jobs should not be resorted to unless absolutely necessary. However, the contractor must, as a general rule, have enough elasticity in his force and plant to handle the current extra work with the same degree of facility and economy as the contract work proper. Extra work must not be continually sacrificed to the contract work proper.

In paying for the use of machines under extra work the engineer will agree with the contractor on the price per hour complete in operation, or where extra work is continuous on the basis of the price per day. Inspectors should compare the time of men and plant on all extra work with the foremen every night and a similar comparison should be made by the superintendent and assistant engineer twice a month.

Forms on finished work should not be removed in less time than from 3 to 14 days, depending on the setting of the cement, the condition of the weather and the height of a day's work. Forms on unfinished work should not be removed in less than from 12 to 72 hours, depending on the foregoing.

On each new part of the finished work the forms should be removed as soon as practicable, so that it may be assured that the method of placing the facing is a good one; if not, there will be a chance to improve upon similar sections of work.

All layers of concrete should be horizontal, ex-

cepting near the skew backs of heavy arches, where they should be inclined as nearly to right angles to the thrust of the arch as may be consistent with a compact concrete. A dryer concrete than is generally used in mass work may properly be used here. The contractor should be required to set wooden blocks from 6 ins. × 6 ins. × 2 ft. to 8 ins. × 8 ins. × 4 ft. in the concrete, taking up approximately 10% of the area in the finish of each day's work. These dowelling blocks should be removed the following day. This is done for bonding purposes, and great care should be taken to see that this rule is carried out at all abutting sections of transverse arch blocks.

All mortar for face work should be made by hand or a regular mortar mixer.

The contractor must not continually change the facing hands who are skilled in this class of work. The uniformity of the appearance of concrete work is desirable, and is dependent largely upon this class of labor.

CONCRETING.—Unreinforced concrete arches should be laid up in alternate transverse blocks (methods employed at the Big Muddy and Connecticut Ave. bridges) as the great weight of the concrete in this class of concrete work causes serious deformation of the center unless the latter be made very heavy. This deformation causes transverse cracks and small fissures if the arch be built up in continuous transverse blocks, and if built up in longitudinal rings the load of the second ring will have a tendency to strike the portion of the center under the first ring, and the third ring will have a tendency to strike the portion of the center under the second ring, etc. In addition to this there would result a warped soffit which might be offensive to the eye.

Transverse and longitudinal arch blocks must be cast continuously, and the contractor must not start such work unless provided with sufficient plant and material to insure the finish of such a section continuously.

Reinforced arches, which as a rule bring a light load on the center, should be built up in longitudinal rings made to incorporate two or three of the steel rib reinforcements. By using this method the steel ribs are better encased and you are enabled to get the separate rings built as monolithic arches from skewback to skewback.

The concrete should be of such consistency in general that a man in walking about in it will sink ankle deep. This may be somewhat cut down in cold weather.

Note the color of the concrete, and if it varies considerably examine for cement. Find out whether the variation is due to the color of the sand, stone or variation in the cement. Occasionally a batch may get into the work with little or no cement in it if the color is not kept in mind.

Keep your work always neat as to the grade of the concrete. If the work is not handled systematically you cannot get first-class work, nor will it be economical to the contractor.

Keep your face work always high, so that any of the concrete water which may accumulate will not go to the face work, for if it does it will weaken your face work and carry to it a lot of slime or laitance; silty sand is not good for face work.

If your concrete is too wet, don't bail out the water, as it is full of cement. (In trench work bailing may be necessary. Dry it up with a relatively dry concrete. Do not permit the hoist-

ing engineers to continually strike the forming with the concrete bucket. Do not permit direct attachments of machinery to the forms, as it will result in vibrations which may be detrimental to your face work.

Use soupy concrete when placed in water, and in muddy water try to carry the concrete work on continuously; otherwise you will have layers of laitance and mud from ⅛-in. to 1 in. or more in thickness, which are weak and will result in the settlement of your completed structure.

In one case on my work this year the top of concrete which was used for sealing the bottom of a coffer dam, and which had been left for about ten days before the coffer dam was pumped out, was found to contain a great deal of this class of rotten material. The bottom of the coffer dam or the top of the seal was very rough, and in the valleys, which varied from 2 to 3 ft. in depth, I found as much as 8 ins. of this useless material.

Don't shovel concrete into water. Place it in as large batches as practicable and lower with bucket or pipe.

Don't dump large quantities of concrete into narrow forms. You will not be able to get sound facing work if you do.

## GENERAL POINTS ON CONCRETING.

Clean all loose silt, dirt and grease from iron. Use wire brushes and putty knives.

Use soupy concrete for concrete-steel work.

Use rammers having special shapes where necessary. Bevel rammers are necessary for the backs of arches. Railroad tampers for heavy steel reinforcements. Short-handled rammers in confined places and long-handled rammers in columns. Fine stone forks are better than

spades on plain face work where the concrete stones are as large as 2 ins.

It ought not to be necessary on first-class work to be continually patching up. Arrises and corners cannot be patched up except by cutting out large sections of the work. Plastering which is put on finished work will not hold unless it is put in very thin layers, and then it is doubtful. Corners can never be satisfactorily patched up by plastering. Good work sometimes may be executed on plane surfaces by first wetting the wall and then rubbing on it a coating from 1-16-in. to ⅛-in. in thickness. It takes a good deal of rubbing to get any results, and too much rubbing generally results in hair cracking as excessive cement is worked to the surface. The less cement is rubbed, the less hair cracking will result. No kind of mortar facing should be richer than 1 : 3, and when cast in place it may be as little as 1 : 4 for plane surfaces; ornamental work should not be leaner than 1 : 3. If conditions are such that plastering a veneer on finished work is necessary, I would use a mortar which was already partially set up; then add water and retemper. The reason that plastered work breaks off is that the mortar in setting up shrinks. The richer it is the more it shrinks, and the shrinkage results in leaving a hair plane between the plaster and the concrete work. The frost does the rest.

Don't leave timber work in the concrete unless it is absolutely necessary.

Note any movement or bulging of the form. Correct, if necessary, by wedging and remodel other similar forms to overcome this trouble.

Bear in mind that an excess of water weakens the concrete a little, increases efflorescence and retards the time of setting.

In work where it is necessary to throw a heavy load upon it in a short time, reasonably dry concrete should be used. Tests indicate that it is probable that wet concrete will be as strong as dry concrete in a year. However, wet concrete certainly bonds the new work better to the old work, and is particularly valuable when encasing steel, as the air is excluded and the steel becomes coated with cement. Excess of water, however, not only results in excess of efflorescence, but also in the amount of laitance or slime which appears on the surface of a day's work.

In a batch mixer (excepting the Haines gravity mixer) it does not make any practical difference as to the order in which the material is entered, excepting that the water should be last. The mixer should be kept clean, which means that it should be cleaned every night. The water should be varied with the amount of moisture in the sand and the stone, and should be greater for porous stone. Remember always that after a rain you need less water in your concrete. The amount of sand should be varied also, so as to get a uniform product with run of crusher. This is a very vital point.

The permeability of concrete may depend upon the cement, but it is certain that it is greater with a dry concrete and less with a well-graded sand and with a sand containing silt. While 10% and even 15% of silt may be desirable for concrete having a low permeability, it is probable that any amount over 10% weakens concrete, and it is certain that it increases the amount of efflorescence and slime which rises to the surface of a day's work.

Inspectors on my work use hand tallying machines to keep track of the number of batches,

and at noon and quitting time they check their tally with the bags at the mixer.

On finished work which is not to be tooled the lagging should be coated with linseed oil. Glycerine leaves a fatty stain. On work which is to be tooled it is not necessary to use oil.

Concrete dumped from large buckets should be lowered as near to the concrete as practicable, particularly when deposited on concrete which is not older than 48 hours, so that the bond between adjacent layers will not be broken.

The most noticeable imperfection in concrete surfaces is the lipping between consecutive day's work. The stiffer the forms, the less the lipping. On account of this lipping I bring each day's work to a horizontal layer by using a straight edge. In mortar facing I find that if extreme care is not taken the steel plate which is ordinarily used between the concrete and the mortar facing drags, leaving an unreasonably large space between the two, and if the rammers are not particularly careful there will be no bond between the two and the mortar facing will flake off.

A great many so-called concrete workers and concrete contractors do not attempt to cast fine arrises, but assume from the start that they will fix up the work by plastering after the forms are removed. Occasionally your details will not turn out as well as they should, and under such circumstances a thin veneer of mortar is permissible, but should only be applied by an expert concrete finisher. Rubbing finished concrete with grout or painting the face with grout is deprecated. The writer once got hold of several barrels of cement rich in free lime, which he unfortunately used to paint a concrete bridge in

order to give it an even finish. The results were very disastrous, and the bridge was a mass of blotches, varying between white and a dirty pink.

Where it is necessary to cast a cornice in place, the top surface of which is comparatively flat, it is impossible to get this finish against a top form. I would leave the top form off, tamp carefully to grade, and as soon as the concrete has a fairly good set, from 3 to 12 hours, I would rub it down to an even grade with a small flat stone or a wooden float. In my judgment, it is not desirable to add any additional mortar to make this finish. However, if you have gotten a poor job on this part of the work and you are practically forced to rub it up, using additional mortar, I would roughen it slightly with a mason's axe, wet it thoroughly and rub a coat of not more than ⅛-in., using a 1 : 3 cement mortar which has been set up three or four hours.

WORK IN COLD WEATHER.—Don't use frozen materials for concrete work. By cutting off the crust of stone or sand you will get unfrozen material. All hard lumps should be thrown out. When concreting below the freezing point the stone and sand should be heated, preferably with a coil of steam pipe or with a steam jet inserted at the points where the material is being removed. In this connection, however, it is well to remember that if the material so steamed is not used at once it will give you more water and therefore more ice to contend with in your pile. With a little care you should be able to place your concrete in the work at a temperature of 60° F., regardless of the temperature of the surrounding atmosphere.

Concrete should be protected from the cold so that it will not freeze. It is believed that if con-

crete freezes only once, and then before setting up, it is not injured by this one freeze, but the time of set is retarded; the bond, however, of the concrete which has been frozen will not be as hard to the unfrozen layers as if it had not been frozen. Mortar facing which is once frozen is permanently injured, due possibly to the expansion which takes place during freezing. There are innumerable coverings for the top surface of concrete to prevent freezing. Canvas, cement bags, tar paper, straw, sand and manure are all used for this purpose. Bear in mind in this connection that concrete generates heat when it sets up, therefore the problem of the engineer is somewhat simplified; my own observations lead me to believe that this generation of heat lasts for at least 30 days.

When canvas is used it should be kept an inch or two away from the concrete, leaving an air space between the concrete and canvas. If this is not practicable I would suggest two layers, if the thermometer is liable to fall to 20° F. Cement bags should be in layers and well lapped; if this is not done the concrete will be frozen between consecutive bags. Tar paper should be well lapped and used as suggested for canvas. Straw should be used at least 1 ft. deep, and, in extreme weather, deeper. In conjunction with tar paper and canvas, it works very well. Manure is the best of materials, as it is a heat generator, but it discolors the concrete (this is seldom of import). Stoves are also used for this purpose, but are going out of use. Steam pipe has been used over boxed areas, but is expensive. In extremely cold weather the laying of steam pipe on the surface of concrete is probably the very best way to protect it from freezing, in spite of the cost. These pipe-lines should be

covered up with canvas or tar-paper so as to keep the heat in.

In the winter time it is well to cut down the area of your concrete work by use of bulkheads, so as to decrease the time of exposure of a single layer, which, of course, will result in running your work up to a greater height for a day's work, thereby necessitating stronger forms. There is no trouble at all in executing heavy masonry work, particularly below ground, in the coldest weather, if your materials are heated. However, in thin work (walls under 2 ft. in thickness) it is somewhat dangerous below 25° F.

Where you have a spaded or mortar finish, extreme care should be taken to protect the work, preferably by covering the outside of the studs with a layer of tar paper. This makes an ice-box sort of an arrangement, leaving an air space of the thickness of your studs between the paper and your lagging. Care should be taken to tack this paper on securely, as it is not infrequent to see paper used in this manner blown off before your concrete has had time to set. Remember that cold weather retards the time of setting of concrete. I have known a number of cases where the time of setting was two or three times as long as in hot weather. This, of course, does not apply to mass concrete.

On thin work I would suggest limiting the time of concreting to 28° on a rising thermometer and 32° on a falling thermometer. On particular work (thin work) I have found the forecast of the Weather Bureau of great assistance in determining whether or not it would be advisable to concrete. During three months of the winter when I was carrying on a very careful piece of work I found the minimum temperatures predicted by the Weather Bureau very accurate indeed.

Where I have used tar paper on the outside of trimming I have found the temperature of the air between the paper and the lagging from 8° to 10° warmer than the outside air at its minimum temperature, and it is well to bear in mind also that the side from which the wind blows is more liable to be frozen than the sides that are protected from the wind. In my own work I take special pains to protect the north and west side of the structure.

In narrow form work where the forms are three or four times as high above the concrete as the least horizontal dimension of the pit, little protection is required—particularly if the temperature of the concrete itself when placed is in the neighborhood of 50° F.—even if the thermometer fall as low as 20° F. (This refers to the top surface of the concrete—of course the vertical surfaces may be affected if not protected as described before in this article.)

When concreting at low temperature, particularly with a mortar facing, I would suggest to the inexperienced engineer cutting out small blocks of the lagging, say, 4 × 12 ins., at different points of the most exposed sides of the work in order to note whether or not the mortar facing is being affected by frost. One morning, when the temperature at 8 a. m. was 10° above zero, with a stiff wind blowing, I found the temperature of the air between the paper and the lagging to be 20°, and upon cutting out the several blocks of lagging I found a few ice crystals on the inside of the lagging, but the mortar facing was warm and was not affected at all. The temperature of the concrete at placing was about 60°. The temperature of the air at the time of concreting was probably a little below 30° F. This same morning I took off from the top sur-

face two layers of cement bags which had been used to protect the top surface of the concrete and found the bags frozen and ice crystals on the under side of the bags. At two or three spots where the bags had not been properly lapped the concrete was frozen to a depth of 1 in. The balance of the concrete was not affected by frost.

CONCRETING IN WATER.—Don't place concrete in running water or still water if it is practicable to get rid of the water.

In still shallow water, deposit the concrete so as to back the water in one direction (of course all concrete placed in water, shallow or deep, should be placed in as large batches as practicable). In running water try to localize the flow in pipe or chutes or by use of bulkheads (bag concrete is good for this purpose), and if this is not practicable deposit the concrete as suggested in still water, working in one direction, backing the water to the low side.

Great care should be taken not to pump the water out of the pit while concreting, if this can be prevented. If you do, you are liable to lose your cement, leaving only the aggregate behind. By locating your pump a good distance from the point of concreting, you may get good results; but great care should be then used and the inspectors should keep their eyes on the water flowing from the pump. If you are losing cement you will, as a rule, be able to detect the fact by the appearance and odor of the water. I have heard recently of two piers whose settlement has been attributed to this oversight.

Concrete dumped under water should, of course, be dumped as close to the bottom as practicable. It is not necessary to ram it; a diver walking over it does more harm, as a rule, than

good by stirring up the cement, which rises to the surface.

I saw one piece of work where concrete was dumped at the surface of the water through 15 ft. of water, and I understand a good hard concrete was formed on the bottom. The concrete was dumped in two-yard batches and was quite wet. The amount of cement which rose to the surface was surprisingly small.

In repair work to masonry walls, to undermined foundations, particularly to river piers, bag concrete is an excellent material. In river work an ordinary cement bag, two-thirds filled with wet concrete, when laid up carefully by a diver, will give good results. This class of work will stand 10 or 12 tons per sq. ft. with a good factor of safety. Bag concrete can also be used on small work for foundations, in running water, where good economy would not warrant a cofferdam and pumping. It can also be used to divert a heavy stream of water (inside a cofferdam) and can afterwards be incorporated in the mass, that is, concreted in.

DECREASING THE PERMEABILITY.—Last year the grouting of a crack in a massive concrete wall suggested the feasibility of decreasing the permeability of porous concrete by drilling holes into the concrete and forcing grout into the concrete with grout pumps. In forcing grout into several holes we noted that it was forced out in small quantities at innumerable points, indicating that we were not only grouting the crack but also the concrete. The concrete was not a porous one.

## ESTIMATING COST.

Contractors in making up their bids should bear in mind that there are all classes of concrete. Its cost varies between $3 and $45 per cu.

yd., and it is up to the contractor to find out where each item of concrete stands between these figures.

The cost depends upon specifications, the customs of a community, the engineer in charge, the market, the demand for labor, kind of labor available, the hours of labor, the location of the work, the cost of materials, the storage room available in order to handle the construction, the haul and the kind of work, the time of year, the climatic conditions, including freshet conditions, and the time allowed to complete the work, including the penalties for failure to finish in the stipulated time. The kind of work is so varied—from foundation mass work requiring shoring and pumping to a highly detailed balustrade—that it is no wonder that unfortunate bids for concrete work occur so often. Every engineer in the concrete field is constantly meeting contractors who have failed in making up bids to consider the various classes of work covered by the bid.

Moreover, reinforced concrete is so new and the demand for this class of design is so great that engineers have not been able to spend as much time as they should in figuring out systems of reinforcement which would not so greatly increase the cost of placing the concrete. This cost varies between 15 cts. per cu. yd. for mass work to $10, and if you want to get cheap work you must get the concrete placed at a reasonable figure. It is only fair to say that a considerable part of the cost referred to is due in part to ornamentation, which goes with the most expensive reinforced work. Narrowness of forms, excessive detail and steel reinforcement are the items which run the cost of placing concrete to such an extraordinary figure.

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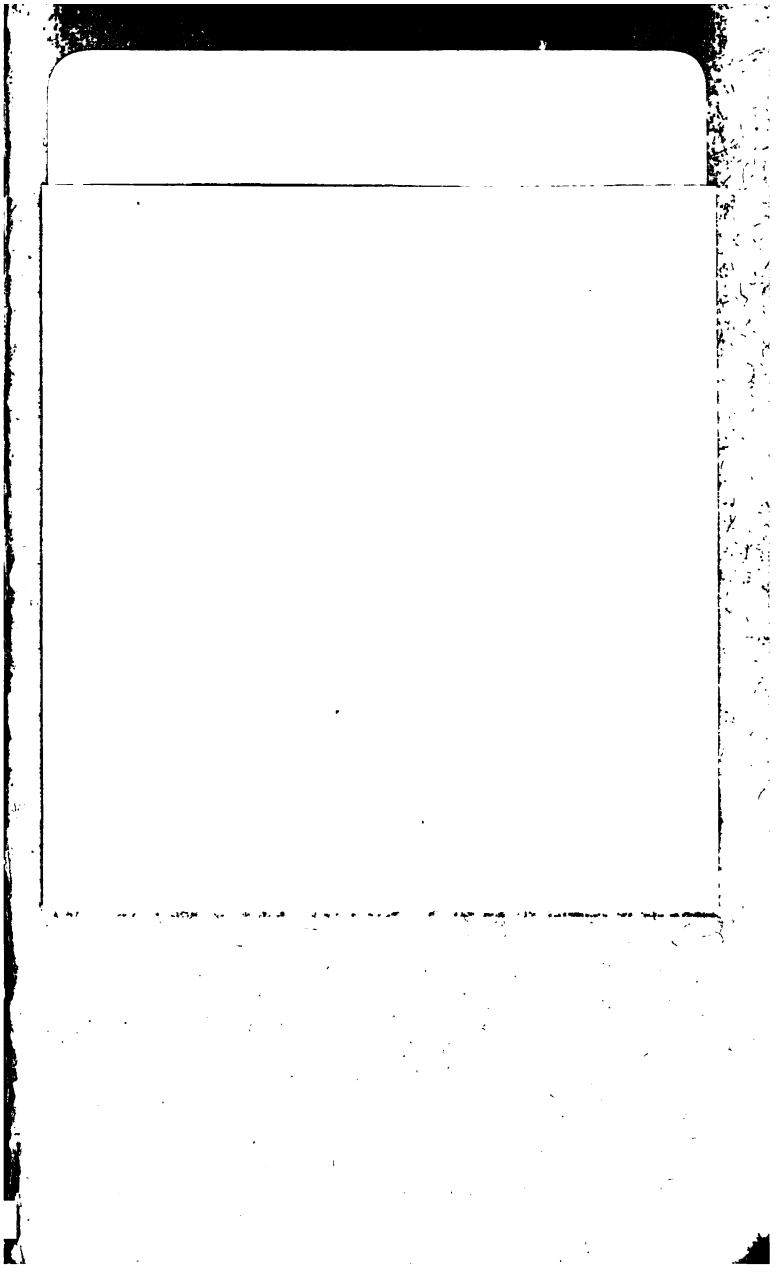
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